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A METHOD AND SYSTEM FOR DELIVERING VIRTUAL REFERENCE STATION DATA

Inventor:

BRENT O'MEAGHER

Prepared by:

WAGNER, MURABITO & HAO LLP

Two North Market Street

Third Floor

San Jose, California 95113

(408) 938-9060

TRMB-1400/JPW/DJR

A METHOD AND SYSTEM FOR DELIVERING VIRTUAL REFERENCE STATION DATA

FIELD OF THE INVENTION

The present invention relates to position determining systems. More specifically, the present invention relates to a broadcast network for determining a geographic position.

BACKGROUND OF THE INVENTION

Real-Time Kinematics (RTK) refers to a surveying system and method which uses two GPS receivers and a communications link between them to determine a position of one receiver relative to the other receiver. In a typical RTK survey system, a first GPS receiver is located at a known position, often a surveyor's landmark or benchmark, or an otherwise surveyed position, and the pseudorange data it collects is sent to the second GPS receiver, often referred to as a "rover," via a radio communications link. The rover is used to determine the relative position of desired points according to the needs of the survey effort. Thus there is a radio transmitter associated with the first receiver, called a reference receiver or a base station receiver, and a radio receiver at the rover. Pseudorange data from the satellites in view from the first receiver at the base station location is combined with data taken at the second rover receiver, and is processed at the rover according to well-known RTK methods to develop a position of the rover relative to the base station position. The typical distance

from base to rover for acceptable accuracy is in the range of 15-30 Km. The errors are due to atmospheric variations which in turn cause changes in the measured path length to the satellites (pseudoranges). Thus for surveying or other positioning systems which must work over larger regions, the surveyor must either place additional base stations in the regions of interest, or move his base stations from place to place. This range limitation has led to the development of more complex enhancements that have superceded the normal RTK operations described above, and in some cases eliminated the need for a base station GPS receiver altogether. This enhancement is referred to as the "Virtual Reference Station" system and method. It is also referred to as Networked RTK.

Network RTK typically uses three or more GPS reference stations to collect GPS data and extract information about the atmospheric and satellite ephemeris errors affecting signals within the network coverage region. Data from all the various reference stations is transmitted to a central processing facility, or VRS control center for Network RTK. Suitable software at the control center processes the reference station data to infer how atmospheric and/or satellite ephemeris errors vary over the region covered by the network. The control center computer processor then applies a process which interpolates the atmospheric and/or satellite ephemeris errors at any given point within the network coverage area and generates a pseudorange correction comprising the actual pseudoranges that would be received at the specified base station

location, now referred to as the Virtual Reference Station, and pseudorange corrections applicable to the region surrounding that location. As in the basic RTK method, where the pseudoranges measured at the base station are delivered to the rover via a radio link, so must the corrected pseudoranges calculated at the VRS control center be delivered to the rover, or rovers doing the actual surveying. Since the VRS control center can be located anywhere, it is not likely to be within normal radio transmission range of the rovers. Typically, prior art delivery methods included using a direct cellular connection between the VRS control center and each rover.

As VRS methods have been accepted and have become widely used, more and more rovers are employed in a survey, the necessity of a dedicated direct connection for each rover has emerged as a financial burden and therefore a limitation of the VRS system. For example, a construction site may have a plurality of roving GPS units working at the same time, each with a dedicated cellular connection to the control center. Additional GPS receivers may be used with construction equipment to, for example, dig a trench for utility lines in an exact location, or grade a road in a particular location. Thus, a plurality of cellular connections may be needed within a relatively compact area for each GPS receiver being used.

Current methods for delivering VRS data to roving mobile position determination units are inadequate. Accordingly, a need exists for a VRS data

distribution system and method that reduces the need for dedicated cellular telephone connections between the various rovers and a distant VRS control center.

SUMMARY OF THE INVENTION

The present invention is a method and system for delivering network-created correction data as part of a Virtual Reference Station activity to a multiplicity of rovers via a concatenated communications link consisting of a single cellular connection, and a radio transmission or broadcasting system. In one embodiment, the location of the radio transmitting system is co-located with a GPS base station that is designated as the position of the local Virtual Reference Station. This GPS base station determines its position using GPS, informs the VRS base station of its location via a cellular link between the local GPS base station and the VRS base station, whereupon the VRS base station generates corrections as if such corrections were actually being generated at the GPS base station. A message, comprising a VRS corrected pseudorange for a specified VRS base station location, is then transmitted via a cellular telephone network to the radio transmitting (broadcasting) system at the designated VRS position, at the GPS base station. The radio transmitter at the GPS base station sends the position correction wirelessly to a rover mobile position determination unit which uses the position correction information to calculate its present location as part of an overall position determining process. The rover position information developed and stored with VRS corrections is much more accurate than an uncorrected GPS position.

Embodiments of the present invention can be used to determine a geographic position with a level of resolution that is comparable with other

existing RTK systems. Because the base station need only be known to a lower level of accuracy, it is not necessary to position it at a surveyed position, such as a benchmark. The position of the virtual reference station will be determined to higher level of accuracy by the VRS control center. Additionally, there is no need for a dedicated cellular connection from the VRS base station to each roving GPS unit in the field. The base station at the designated Virtual Reference Station location can wirelessly forward the VRS pseudoranges and corrections it receives via the cellular telephone network to the roving GPS units using, for example, a radio transmitter or transceiver. In one embodiment, the base station can be used as a rover as well as the base station for other roving GPS units in the vicinity.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the present invention and, together with the description, serve to explain the principles of the invention. Unless specifically noted, the drawings referred to in this description should be understood as not being drawn to scale.

FIGURE 1 is a flowchart of a method for delivering Virtual Reference Station data accordance with embodiments of the present invention.

FIGURES 2A, 2B, and 2C are block diagrams of embodiments of exemplary devices used in a system for delivering Virtual Reference Station data in accordance with embodiments of the present invention.

FIGURE 3 is a diagram showing an exemplary system for determining a geographic position in accordance with embodiments of the present invention.

FIGURE 4 is a flowchart of a method for delivering Virtual Reference Station data in accordance with embodiments of the present invention.

FIGURES 5A, 5B, and 5C are flow charts of methods for delivering Virtual Reference Station data in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings. While the present invention will be described in conjunction with the following embodiments, it will be understood that they are not intended to limit the present invention to these embodiments alone. On the contrary, the present invention is intended to cover alternatives, modifications, and equivalents which may be included within the spirit and scope of the present invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, embodiments of the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the present invention.

Figure 1 is a flowchart of a method 100 for delivering Virtual Reference Station data in accordance with embodiments of the present invention. For clarity, the following discussion will refer to Figures 2A, 2B, and 2C as well as Figure 3 to explain embodiments of the present invention. In step 110 of Figure 1, a data message is created comprising pseudorange data derived for a designated location and pseudorange corrections for a region surrounding the designated location. In embodiments of the present invention, a Virtual

Reference Station network is used to collect GPS data and extract information about the atmospheric and satellite ephemeris errors affecting signals within the network coverage region. Data from various reference stations in the network is transmitted to a central processing facility, or VRS control center for Network RTK. Suitable software at the VRS control center processes the reference station data to infer how atmospheric and/or satellite ephemeris errors vary over the region covered by the network. The VRS control center computer processor then applies a process which interpolates the atmospheric and/or satellite ephemeris errors at any given point within the VRS network coverage area and generates a pseudorange correction comprising the actual pseudoranges that would be received at a designated location in the network coverage area. The VRS control center also generates pseudorange corrections applicable to a designated region surrounding the designated location.

In step 120 of Figure 1, the data message of step 110 is sent via a cellular telephone connection between the VRS control station and a base station located in a designated region surrounding the designated location. As in the basic RTK method, wherein the pseudoranges measured at a base station are delivered to a rover via a radio link, so must the corrected pseudoranges calculated at the VRS control center be delivered to the base station located at a designated location, or within a designated region surrounding the designated location. In embodiments of the present invention, the data message is sent from the VRS control center to the base station via a

cellular telephone network. In embodiments of the present invention, the designated location of the base station is determined using a Geographic Positioning System (GPS) receiver located proximate to the base station. For example, the base station may be a Real-time Kinematics (RTK) base station comprising a GPS receiver and communications devices. The GPS receiver of the base station can be used to derive an initial position fix of the designated location. In another embodiment, the mobile position determination unit comprises a GPS receiver and is located proximate to the base station. The GPS receiver of the mobile position determination unit can be used to derive an initial position fix of the designated location for the base station.

In step 130 of Figure 1, the data message is transmitted from the base station to a mobile position determination unit using a radio transmitter. In embodiments of the present invention, the pseudorange data derived for the designated location and the pseudorange corrections for a designated region surrounding the designated location are sent to at least one mobile position determination unit via the base station. In accordance with embodiments of the present invention, the data message is sent from the base station to the mobile position determination unit using a radio transmitter.

Embodiments of the present are advantageous over conventional VRS networks and methods because dedicated cellular telephone connections between each mobile position determination unit and the VRS control center

are not necessitated in embodiments of the present invention. The need for a dedicated cellular connection for each mobile position determination unit is financially burdensome and is needlessly redundant when a plurality of mobile position determination units are being used in a relatively compact region surrounding the base station. In embodiments of the present invention, only a single cellular telephone connection, between the VRS control center and the base station, is necessary to send the pseudorange corrections and the derived pseudorange data. This data is then forwarded to the mobile position determination units using a radio transmitter located at the designated location.

Figures 2A, 2B, and 2C are block diagrams of embodiments of exemplary base stations and mobile position determination units used in a system 200 for delivering virtual reference station data in accordance with embodiments of the present invention. While the following embodiments of system 200 are recited specifically, it is appreciated that the present invention is not limited to these embodiments alone. In Figure 2A, base station 210 comprises a GPS module 211, a Bluetooth module 212, a radio module 213, and a cellular telephone module 214. While the present invention recites a GPS module specifically, embodiments of the present invention are well suited to utilize other navigational systems such as the GLONASS system, or the Galileo system currently under development.

Mobile position determination unit 220 comprises a GPS module 221, a Bluetooth module 222, and a radio module 223. Mobile position determination unit 220 may also comprise optional cellular telephone module 224 either integrated into unit 220 or, for example, carried by an operator (e.g., a cell phone). Other components of base station 210 and mobile position determination unit 220 that are not shown can include a processor for processing digital information, data storage devices such as memory, magnetic or optical storage, and/or removable data storage devices. Additionally, antennas for the various communication devices are not shown for clarity.

In the embodiment of Figure 2A, an initial location of base station 210 can be determined using GPS module 211. In other words, an initial position fix of the designated location of base station 210 is determined using GPS module 211. Alternatively, the initial location of base station 210 can be determined using GPS module 221 of mobile position determination unit 220. This initial location is then transmitted to the VRS control center via a cellular telephone network using, for example, cellular telephone module 214. VRS control center 310 determines the expected pseudoranges for base station 210 by, suitable processing of the pseudoranges obtained from the various distant reference stations in the VRS network. The pseudorange data is then sent to base station 210 via the cellular telephone network. For example, an un-aided GPS unit can fix its current position with a resolution of approximately 10 meters. However, when the pseudorange data from VRS control center 310 is

correlated with the initial position fix, a resolution of 1 centimeter over 10 kilometers is realized in the horizontal plane, and 2 centimeters over 10 kilometers is realized in the vertical plane is realized.

As long as base station 210 remains within a designated region surrounding the designated location the VRS base station will continue to send pseudorange data and pseudorange corrections based upon the initial designated position. If base station 210 is moved outside of the designated region, a new set of pseudorange data and pseudorange corrections may be determined using VRS network 300.

In Figure 2B, base station 210 comprises two separate units. The first unit 210a comprises a GPS module 211, a radio module 213, and a first Bluetooth module 212a. The second unit 210b comprises a second Bluetooth module 212b and a cellular telephone module 214. Mobile position determination unit 220 comprises GPS module 221, Bluetooth module 222, radio module 223 and optional cellular telephone module 224. In the embodiment of Figure 2B, the initial location of base station 210 can be determined using GPS module 211 of first unit 210a. Alternatively, the initial location of base station 210 can be determined using GPS module 221 of mobile position determination unit 220. In one embodiment, this initial location is sent from first unit 210a to second unit 210b wirelessly via Bluetooth modules 212a and 212b. However, while the present embodiment recites sending the

initial location to second unit 210b wirelessly, embodiments of the present invention are well suited for sending the initial location from first unit 210a to second unit 210b using other methods such as a parallel or serial data connection. Additionally, embodiments of the present invention are well suited to using other wireless communications such as radio transceivers for sending the initial location from first unit 210a to second unit 210b. Second unit 210b sends the initial location to the VRS control center via a cellular telephone network using cellular telephone module 214. The pseudorange data of the designated location of base station 210 is then determined as described above.

In Figure 2C, base station 210 comprises a radio module 213, a cellular telephone module 214, and an optional Bluetooth module 212. Mobile position determination unit 220 comprises GPS module 221, radio module 223, an optional Bluetooth module 212, and an optional cellular telephone module 224. In the embodiment of Figure 2C, the initial location of base station 210 is determined using the GPS module 221 of mobile position determination unit 220. For example, position determining 220 unit can be located proximate to base station 210 and the initial location for base station 210 is determined using GPS module 221. The initial location can be sent wirelessly to base station 210 using either Bluetooth module 222, radio module 223, or cellular telephone module 224. While the present embodiment recites mobile position determination unit 220 sending the initial location to base station 210 wirelessly, embodiments of the present invention are well suited to using other

communication methods such as a serial or parallel data connection, etc. Base station 210 receives the initial location using radio module 213, Bluetooth module 212, or cellular telephone module 214 and sends it to VRS control center 310 via a cellular telephone network connection using cellular telephone module 214. The pseudorange data of the designated location of base station 210 is then determined as described above as well as the pseudorange corrections for the designated region surrounding the designated location of base station 210.

Referring now to Figure 3, which shows an exemplary broadcast network 300 which can be utilized in embodiments of the present invention. In one embodiment, network 300 is a VRS network comprising a VRS control center 310 that is communicatively coupled with a plurality of reference stations (e.g., reference stations 321, 322, 323, 324, 325, 326, 327, and 328 of Figure 3). In embodiments of the present invention, there are a variety of methods for communicatively coupling VRS control center 310 with reference stations 321-328 such as wireless transmissions, or a Public Switched Telephone Network (PSTN).

The reference stations are located at surveyed positions and are used to establish the magnitude of position fix errors (e.g., ionospheric and tropospheric delay, satellite orbit errors, satellite clock errors, etc.) incurred at that location when receiving a satellite based position fix such as a GPS position fix. As a

result of these errors, a GPS receiver may provide an inaccurate position fix. However, comparing the position fix from the GPS receiver with the surveyed position of the reference station facilitates establishing the magnitude of the position fix error at that location. A pseudorange correction can then be derived which, when correlated with the position fix, accurately determines the initial position of the GPS receiver. In embodiments of the present invention, this then becomes the designated location of the Virtual Reference Station.

In embodiments of the present invention, other processes are typically used to provide further corrections, as described in an article titled "Broadcast Network RTK Transmission Standards and Results," by Nicholas Talbot, Gang Lu, Timo Allison, and Ulrich Vollath, and incorporated as reference herein in its entirety can be accessed at the following URL:

http://trl.trimble.com/dscgi/ds.py/Get/File-110017/Broadcast_Network_RTK.pdf.

Another article describing Virtual Reference Station processing titled, "Multi-Base RTK Positioning Using Virtual Reference Stations," by Ulrich Vollath, Alois Buecherl, Herbert Landau, Christian Pagels, and Bernhard Wagner, and incorporated as reference herein in its entirety can be accessed at the following URL:

http://trl.trimble.com/dscgi/ds.py/Get/File-93153/ION2000-Paper-MultiBase.doc.

An additional article describing VRS processing titled, "Long-Range RTK Positioning Using Virtual Reference Stations," by Ulrich Vollath, Alois Deking,

Herbert Landau, and Christian Pagels, and incorporated as reference herein in its entirety can be accessed at the following URL: http://trl.trimble.com/dscgi/ds.py/Get/File-93152/KIS2001-Paper-LongRange.pdf.

Determining the pseudorange data for the designated location and the pseudorange corrections is typically performed at VRS control center 310. Using the data from the various other reference stations, VRScontrol center 310 can then mathematically determine the appropriate corrections for pseudoranges measured by rovers at a given location in the coverage region of network 300. For example, VRS control center 310 can calculate pseudorange corrections for a navigation receiver 331a using the information sent by reference stations 321 and 324. Similarly, VRS base station/control center 310 can calculate pseudorange corrections for a navigation receiver 331b using the error information sent by reference stations 321, 323, and 324.

In the present embodiment, the designated location (e.g., location 330 of Figure 3) of a VRS base station (e.g., base station 210) is determined using VRS network 300. In one embodiment, a GPS position fix of the initial position of base station 210 is determined and sent to VRS control center 310 using, for example, cellular network 360. VRS control center 310 then determines expected pseudoranges and corrections for pseudoranges in that region for base station 210 using the data generated by reference stations in the vicinity (e.g., reference stations 324, 326, and 327).

Referring again to step 120 of Figure 1, a data message is sent from VRS control center 310 to base station 210 comprising the pseudorange data for GPS receivers at the designated location 330 and pseudorange corrections for a designated region surrounding location 330 (e.g., region 340 of Figure 3) via cellular network 360.

Referring again to step 130 of Figure 1, the data message containing the expected pseudoranges and pseudorange corrections appropriate for this region is sent from the base station 210 to a mobile position determination unit using a radio transmitter (e.g., radio module 231 of Figures 2A, 2B, and 2C). The pseudorange and correction data can then be used to determine the position of a roving mobile position determination unit 220. As long as mobile position determination unit 220 is within a designated region surrounding the designated location of the virtual reference station (e.g., within region 340 of Figure 3) of base station 210, the pseudorange data and pseudorange corrections received by base station 210 in step 120 can be used to determine the current position of mobile position determination unit 220 using standard RTK methods.

Since pseudorange data is taken and processed second by second, the data stream from the VRS control center must be delivered in real time, for the duration of the survey by the mobile position determination units. This method

of delivering all necessary data to a single point for redistribution via alternate, less expensive communications channels represents a large potential savings for surveyors. For example, at a construction site it is not uncommon to find multiple mobile position determination units used for surveying purposes in addition to multiple mobile position determination units being used in conjunction with heavy machinery such as bulldozers and back-hoes. All of these units may be able to utilize the same pseudorange correction from the VRS base station if they are within a given radius of the virtual reference station.

Embodiments of the present invention reduce the need for multiple cellular telephone connections because the base station sends the position correction to mobile position determination units using, for example, the Bluetooth module 212, or the radio module 213. As a result, only a single cellular telephone connection is needed, between the base station and the VRS control center, in embodiments of the present invention.

Another advantage of the present invention is that in many conventional systems, the roving mobile position determination units typically have only a radio receiver. In embodiments of the present invention, radio module 223 is a radio transceiver that can send satellite data to, and receive satellite data from, base station 210. In the past a radio transceiver was not used in roving mobile position determination units because of size, weight, and power consumption issues. However, radio transceiver modules are currently available having the

issues. However, radio transceiver modules are currently available having the same physical package as previous radio receiver modules and only draw a half watt of power when transmitting. As a result, the present invention can utilize a radio transceiver in the mobile position determination unit (e.g., mobile position determination unit 220 of Figures 2A, 2B, and 2C) without any significant increase in size or weight. Thus, two-way communications links can be established in the field between base station 210 and a plurality of mobile position determination units 220 without incurring additional cellular telephone charges realized in conventional VRS systems.

In one embodiment, radio modules 213 and 223 operate in the UHF spectrum in the range of approximately 450-470 MHz. In another embodiment, radio modules 213 and 223 operate in the VHF spectrum in the range of approximately 150-170 MHz. In yet another embodiment, radio modules 213 and 223 are spread spectrum transceivers and operate in the range of approximately 900 MHz. While the present embodiments recite these frequency ranges specifically, embodiments of the present invention are well suited to operate in other frequency ranges as well, for example, in unlicensed bands such as 2.4 GHz under Part 15 of the FCC Rules (see CFR 47).

An additional advantage of the present invention is that base station 210 can be also used as a roving mobile position determination unit after the VRS base station has determined a more accurate position for the designated VRS

location, which is initial location of the base station. For example, referring again to Figure 2A, the base station may comprise a GPS module, a Bluetooth module, a radio module, and a cellular telephone module. After receiving the pseudorange data and pseudorange corrections from VRS control center 310 and determining its current position, base station 210 can be moved to a second position within region 340 and used as a roving unit in a manner similar to mobile position determination unit 220. As long as the base station stays within a given radius (e.g., within region 340 of Figure 3) of that designated location (e.g., location 330 of Figure 3), the pseudorange correction data received can be correlated with subsequent position fixes. In such an implementation, base station 210 and mobile position determination unit 220 can both be used as mobile position determination units. In conventional RTK systems, the GPS unit used to transmit the position correction must remain in a fixed position above a known, surveyed position. As a result, one GPS unit is unavailable for use as a roving surveying unit.

Figure 4 is a flowchart of a method 400 for delivering Virtual Reference Station data in accordance with an embodiment of the present invention. In step 410 of Figure 4, data is collected from a plurality of reference stations (e.g., reference stations 321-328 of Figure 3) to derive pseudorange data for a designated location (e.g., location 330 of Figure 3) and to derive pseudorange corrections for a designated region surrounding the designated location (e.g., region 340 of Figure 3).

In step 420 of Figure 4, a data message, comprising the pseudorange data and the pseudorange corrections, is send to a base station (e.g., base station 210 of Figures 2A, 2B, and 2C). As described above, the pseudorange data and pseudorange corrections are sent from VRS control center 310 to base station 210 using cellular network 360. The pseudorange data and pseudorange corrections can be used to determine the location of base station 210 and/or mobile position determination units 220 with a greater resolution than is achieved using an un-aided GPS position fix.

In step 430 of Figure 4, the data message is transmitted from the base station to a mobile position determination unit (e.g., mobile position determination unit 220 of Figures 2A, 2B, and 2C) using a radio transmitter (e.g., radio module 213 of Figures 2A, 2B, and 2C). expected pseudorange at the VRS base station and the pseudorange corrections are used by the mobile position determination units, along with data received from the satellites, to determine the geographic position the rover, again relative to the precise position of the VRS. As described above, while mobile position determination unit 220 is within a designated region surrounding designated location 330, the expected pseudorange at the VRS (e.g., base station 210 located at designated location 330) and the pseudorange corrections are used to more accurately determine the present position of the mobile position determination unit. For example, referring again to Figure 3, a first measurement of mobile position determination unit 220 is made. This measurement is then corrected using the

pseudorange corrections to more accurately determine the geographic position of mobile position determination unit 220. When mobile position determination unit 220 is moved to a second position, a second measurement of its position is made. As long as mobile position determination unit 220 is within a given radius of base station 210, the pseudorange data and pseudorange corrections sent by VRS control center 310 can be processed with this second position measurement to obtain a more accurate position fix for mobile position determination unit 220.

Figures 5A, 5B, and 5C are flow charts of methods for delivering Virtual Reference Station data in accordance with embodiments of the present invention. In step 511 of Figure 5A, GPS measurement data is collected from a plurality of reference stations. As described above, VRS control center 310 utilizes GPS data from reference station 321-328 to determine the magnitude of errors affecting signals within the network coverage area.

In step 512 of Figure 5A, RTK/VRS corrections are generated at a VRS control center. Using the data collected in step 511, VRS control center 310 generates RTK/VRS pseudorange corrections that can be used to determine a geographic position more precisely.

In step 513 of Figure 5A, a cellular telephone call is initiated by a base station for the VRS control center to send RTK/VRS corrections. In

embodiments of the present invention, base station 210 requests virtual reference station data for a designated location. In embodiments of the present invention, this request is conveyed using a cellular telephone connection. Typically, base station 210 sends an initial position fix to VRS control center 310 so that pseudorange data for that designated location can be generated.

In step 514 of Figure 5A, the VRS control center sends RTK/VRS corrections using a cellular telephone network. In embodiments of the present invention, VRS control center 310 will then generate pseudorange data for a designated location (e.g., location 330 of Figure 3) for base station 210 and pseudorange corrections for the designated region surrounding base station 210 (e.g., region 340 of Figure 3). In embodiments of the present invention, the pseudorange data and pseudorange corrections are sent to base station 210 via cellular network 360.

In step 515 of Figure 5A, the base station broadcasts VRS correction data to a mobile position determination unit using a radio link. In embodiments of the present invention, base station 210 broadcasts the pseudorange data and pseudorange corrections to mobile position determination unit 220 using, for example, radio module 213 or Bluetooth module 212.

In step 516 of Figure 5A, the mobile position determination unit receives the VRS correction data. In embodiments of the present invention, mobile

position determination unit 220 receives the pseudorange data and pseudorange corrections using, for example, Bluetooth module 222 or radio module 223. The mobile position determination unit then uses the pseudorange data and pseudorange corrections to more precisely determine its present location.

Referring now to Figure 5B, in step 521, GPS measurement data is collected from a plurality of reference stations. As described above, VRS control center 310 utilizes GPS data from reference station 321-328 to determine the magnitude of errors affecting signals within the network coverage area.

In step 522 of Figure 5B, RTK/VRS corrections are generated at a VRS control center. Using the data collected in step 521, VRS control center 310 generates RTK/VRS pseudorange corrections that can be used to determine a geographic position more precisely.

In step 523 of Figure 5B, a mobile position determination unit requests VRS correction data from a base station. In embodiments of the present invention, mobile position determination unit 220 initiates generating VRS correction data by sending a message to base station 210 requesting VRS correction data.

In step 524 of Figure 5B, a cellular telephone call is initiated by a base station for the VRS control center to send RTK/VRS corrections. In response to the message from mobile position determination unit 220, base station 210 contacts VRS control center 310 via cellular network 360 and requests VRS correction data.

In step 525 of Figure 5B, the VRS control center sends RTK/VRS corrections using a cellular telephone network. In embodiments of the present invention, VRS control center 310 will then generate pseudorange data for a designated location (e.g., location 330 of Figure 3) for base station 210 and pseudorange corrections for the designated region surrounding base station 210 (e.g., region 340 of Figure 3). In embodiments of the present invention, the pseudorange data and pseudorange corrections are sent to base station 210 via cellular network 360.

In step 526 of Figure 5B, the base station broadcasts VRS correction data to the mobile position determination unit using a radio link. In embodiments of the present invention, base station 210 broadcasts the pseudorange data and pseudorange corrections to mobile position determination unit 220 using, for example, radio module 213 or Bluetooth module 212.

In step 527 of Figure 5B, the mobile position determination unit receives the VRS correction data. In embodiments of the present invention, mobile

position determination unit 220 receives the pseudorange data and pseudorange corrections using, for example, Bluetooth module 222 or radio module 223. The mobile position determination unit then uses the pseudorange data and pseudorange corrections to more precisely determine its present location.

Referring now to Figure 5C, in step 531, GPS measurement data is collected from a plurality of reference stations. As described above, VRS control center 310 utilizes GPS data from reference station 321-328 to determine the magnitude of errors affecting signals within the network coverage area.

In step 532 of Figure 5C, RTK/VRS corrections are generated at a VRS control center. Using the data collected in step 531, VRS control center 310 generates RTK/VRS pseudorange corrections that can be used to determine a geographic position more precisely.

In step 533 of Figure 5C, a mobile position determination unit requests VRS correction data from the VRS control center. In embodiments of the present invention, a request for VRS correction data is conveyed from the mobile position determination unit directly to the VRS control center. For example, a user may initiate a cellular telephone call using optional cellular telephone module 224 (e.g., a cellular telephone) by calling VRS control center

310 directly. The user could then indicate a particular base station in the network for VRS control center 310 to contact. Upon indicating which base station to contact, the user can terminate the cellular connection with VRS base station 310 because the VRS data will be sent from base station 210 to the mobile position determination unit using a radio transmitter.

In step 534 of Figure 5C, the VRS control center initiates a cellular telephone connection with the base station and requests a position fix. VRS control center 310 then contacts base station 210 and requests an initial position fix of its current location. Using this information, VRS control center 310 can then generate pseudorange data for base station 210 and pseudorange corrections for the designated region surrounding base station 210.

In step 535 of Figure 5C, the base station sends a position fix to the VRS control center. Base station 210 then determines an initial position fix of its current location using, for example, GPS module 211 or GPS module 221. This initial position fix is then sent to VRS control center 310 via cellular network 360.

In step 536 of Figure 5C, the control center sends RTK/VRS corrections using a cellular telephone network. In embodiments of the present invention, VRS control center 310 will then generate pseudorange data for a designated location (e.g., location 330 of Figure 3) for base station 210 and pseudorange corrections for the designated region surrounding base station 210 (e.g., region

340 of Figure 3). In embodiments of the present invention, the pseudorange data and pseudorange corrections are sent to base station 210 via cellular network 360.

In step 537 of Figure 5C, the base station broadcasts VRS correction data to the mobile position determination unit using a radio link. In embodiments of the present invention, base station 210 broadcasts the pseudorange data and pseudorange corrections to mobile position determination unit 220 using, for example, radio module 213 or Bluetooth module 212.

In step 538 of Figure 5C, the mobile position determination unit receives the VRS correction data. In embodiments of the present invention, mobile position determination unit 220 receives the pseudorange data and pseudorange corrections using, for example, Bluetooth module 222 or radio module 223. The mobile position determination unit then uses the pseudorange data and pseudorange corrections to more precisely determine its present location.

The preferred embodiment of the present invention, a method and system for determining a geographic position, is thus described. While the present invention has been described in particular embodiments, it should be appreciated that the present invention should not be construed as limited by such embodiments, but rather construed according to the following claims.